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## For all humankind: A framework for responsible spacefaring

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Centre for International  
Governance Innovation

CIGI Papers No. 348 – February 2026

# For All Humankind: A Framework for Responsible Spacefaring

Daniel Munro





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## About the Author

**Daniel Munro** is a senior fellow in the Innovation Policy Lab at the Munk School of Global Affairs and Public Policy; director of research and innovation at Actua, Canada's leading youth STEM (science, technology, engineering and math) outreach organization; and co-director of Shift Insights, a research shop that examines the social, technological and economic challenges and opportunities facing Canada. His research and writing span science, technology and innovation policy; skills and education; and applied ethics, including responsible innovation and space ethics. A frequent contributor to CIGIonline and other publications, Dan has also taught political science, philosophy and innovation studies at the University of Toronto, Western University, the University of Ottawa and Queen's University. He holds degrees from the University of Toronto (B.A.), Western University (M.A.) and M.I.T. (Ph.D.).

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## Executive Summary

As spacefaring rapidly expands to include more and different kinds of stakeholders, activities, benefits and risks, we need to think more broadly about what we are doing in space, especially through social, environmental and ethical lenses. What do we want from space? How should benefits and risks be distributed? What values should guide decision making, and who ultimately decides? Building on work in technology ethics and governance, this paper describes a responsible innovation framework that could help steer spacefaring in ways that are both innovative and responsible. Highlighting criteria of anticipation, reflexivity, inclusion, responsiveness and distributive fairness, the paper examines three areas where the approach could help secure a better space future for all: managing low-Earth orbit (LEO) activities, space resource management and the Artemis missions. While acknowledging that responsible innovation is a highly aspirational ideal, especially in the context of rising authoritarianism and persistent geopolitical tension, the paper maintains that aspirational frameworks are essential to safe and responsible spacefaring.

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## Introduction

Writing less than a year after the Soviet Union launched the Sputnik satellite — an event that shocked the United States into accelerating a space program that would ultimately land men on the Moon — the philosopher Hannah Arendt observed a peculiar theme in contemporary discourse. She noted that “the immediate reaction [to Sputnik] was relief about the first ‘step toward escape from men’s imprisonment to the Earth’” (Arendt 1958, 1). That sentiment, repeated in various ways by others, echoed a line on the funeral obelisk of the Russian rocket scientist, Konstantin Tsiolkovsky,<sup>1</sup> who had died more than two decades earlier: “Mankind will not remain bound to the Earth forever” (ibid.).

That some people view Earth as a prison and outer space as a kind of liberation was not surprising for

Arendt. Humanity’s desire for freedom from real or perceived constraints is nothing new. Arendt wondered, however, whether the recent “flight from the Earth into the universe” might accelerate a sense of alienation, and damage our capacity to think and act in life-affirming, moral ways (ibid., 6). While Sputnik revealed new possibilities for humanity, Arendt also saw it as a challenge to clear thinking about who we are, what we want from science and technology, and what we are willing to endure in pursuits to improve the human condition. As the first space age was dawning, Arendt urged us “to think what we are doing” (ibid.).

In the nearly 70 years since Arendt wondered about the implications of Sputnik, humanity has made profound leaps in spacefaring. The technological and engineering advances required to launch rockets, communicate with spacecraft, place objects in orbit, land spacecraft on celestial bodies and manage safe re-entry are stunning. The benefits they enable have transformed the human condition. At the same time, spacefaring has generated risks that we have not adequately addressed. Efforts to track and avoid collisions among objects in orbit, as well as understand and address the environmental effects of launch emissions and re-entry debris, are barely keeping up with the current pace of launches. We have not grappled with the possibility that current space activities could block future and potentially better space-related innovation. And while concerns about how to fairly distribute access to space and its benefits have been articulated in key agreements, such as the Outer Space Treaty (OST), operationalizing and adhering to those principles has played a minor role at best in the current space age.

With the world’s leading spacefaring nation, the United States, quickly descending into authoritarianism, it is a challenging time to think about responsible behaviour in space, let alone hope for action aligned with global democratic norms. But think and hope we must. The stakes for humanity are too high to do otherwise. While scientists, engineers and technicians have thought deeply about how to launch things and people, we need to think more broadly about what we are doing and what we hope to achieve from spacefaring, especially through social, environmental and ethical lenses. What do we want from spacefaring activities? How should benefits and risks be distributed? What values should guide deliberation, and who ultimately decides?

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<sup>1</sup> See [www.space.com/19994-konstantin-tsiolkovsky.html](http://www.space.com/19994-konstantin-tsiolkovsky.html).

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## Thinking About Responsible Spacefaring

One way to address these questions is through a responsible innovation framework. Over the past few decades, scholars and practitioners working in a variety of science and technology fields have reflected on the ethical, environmental, economic and social implications of innovation and proposed criteria and methods to guide it in ways that minimize risk and generate benefits for all (Jonas 1984; Stilgoe, Owen and Macnaghten 2013; von Schomberg 2015). Given the accelerating pace of space-related activities and an aspiration to ensure space activities are “carried out for the benefit and in the interests of all countries...[and] all [hu]mankind,”<sup>2</sup> responsible innovation offers a promising approach to shape our collective space future.

This paper outlines the key features of a framework for responsible innovation and illustrates how it can help steer spacefaring in ways that are both innovative and responsible. The first section characterizes the current space age, highlighting the emergence of new actors, activities and technologies, as well as the opportunities and risks they present. The next section discusses key features of the responsible innovation framework and draws out its relevance to spacefaring. While the paper acknowledges two criticisms of the approach, it maintains that a responsible innovation framework for spacefaring is valuable in helping think through current and future governance issues. Finally, in the third section, the paper examines three areas where deploying a responsible innovation approach could help secure a better space future for all — managing LEO activities, space mining and the Artemis missions.

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2 Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies, 27 January 1967, 18 UST 2410, 610 UNTS 205, 61 ILM 386 (entered into force 10 October 1967).

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## What’s Up in Space? Opportunities, Risks and Trajectories

Spacefaring has changed dramatically over the past seven decades. From Sputnik in 1957 and the Apollo missions of the 1960s and 1970s, to the Space Shuttle missions between 1981 and 2011 and Chris Hadfield’s five-month command of the International Space Station in 2013, space activities were significant events garnering widespread media coverage and public interest. While attention to each one varied, the launches were still rare and significant enough that the general public, if not watching live, was nevertheless aware. Over the past decade, however, exponential growth in launch activity and shifts in the kinds of actors involved have dramatically altered spacefaring and public perceptions of it.

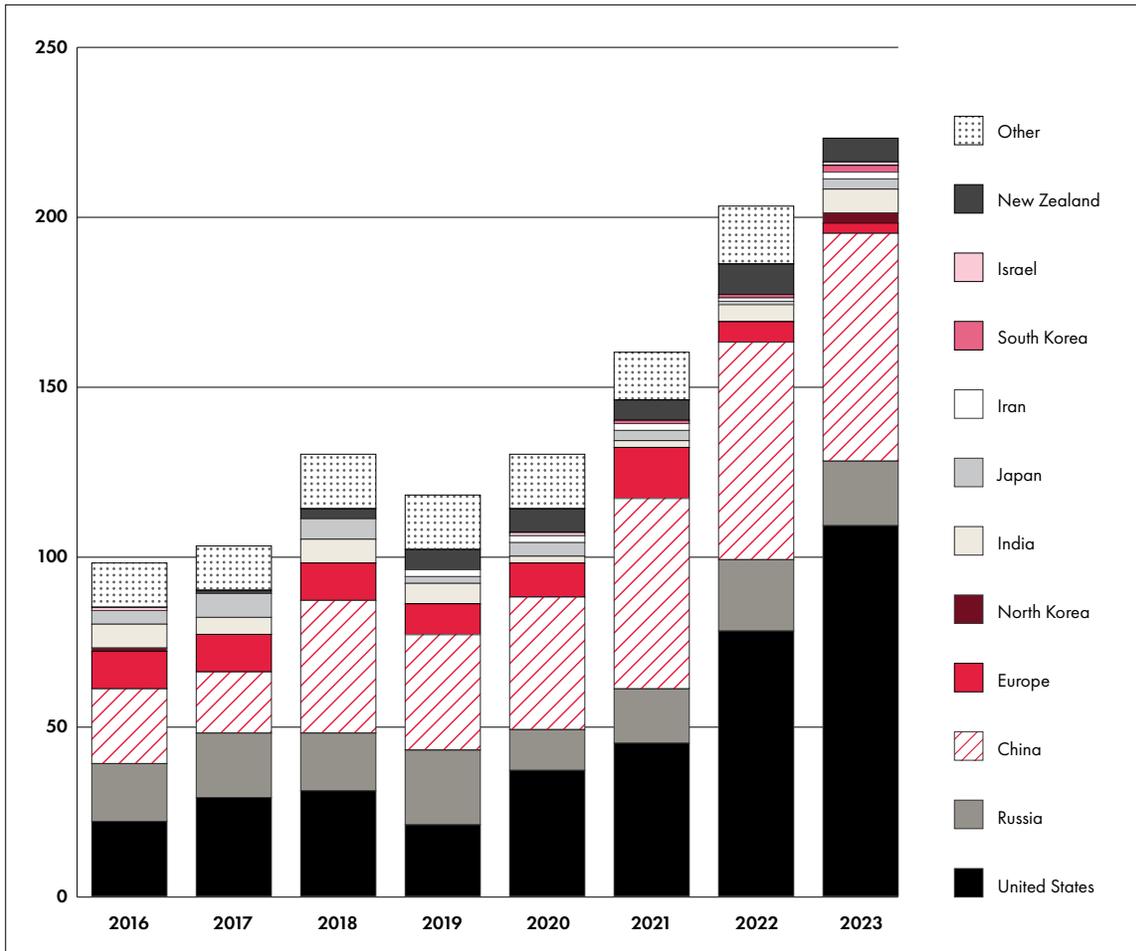
### What and Who Are in Space?

Rocket launches and space object deployment have become almost routine events:

- In 2023, there were 223 orbital launch attempts with 212 successfully reaching orbit — nearly three times more than the 85 launch attempts made in 2016 (McDowell 2024, 4).
- Close to 3,000 satellites were deployed into orbit in 2023 — an order of magnitude more than the 224 deployed in 2016 (ibid., 9).
- By the end of 2023, there were nearly 28,000 objects (10 cm or more in diameter) in orbit around Earth, with only one-third categorized as *active* satellites. The remaining two-thirds include dead payloads (3,146 objects), rocket bodies (1,993), debris from previous uses of anti-satellite weapons (3,068), collision debris (1,188) and other debris (7,810) (ibid., 25).

Along with a dramatic increase in the number of launches, payloads and orbiting objects, there have been notable shifts in the countries and kinds of actors involved. Of the launch attempts made in 2023, just under half (109) were made from the United States, while more than one-quarter (63) were launched from China and nearly one-tenth from Russia. The remainder included launches from New Zealand, India, Europe, Japan, North

Figure 1: Orbital Launch Attempts by Country



Data source: McDowell (2024, 4).

Korea, South Korea, Iran, Israel and a few others.<sup>3</sup> Whereas in the past, governing space was largely about coordinating the activities of two main and a couple of other players, the current space age is a genuinely multi-country, multilateral challenge.

Equally significant is the rise of private sector involvement in spacefaring. While 78 launches in 2023 were made by government space agencies, more than half (132) were launched by private companies for commercial clients and 13 by private companies for government clients (ibid., 7). Three-quarters of commercial launches were executed by SpaceX alone. Of the nearly 28,000 objects in orbit, roughly 6,000 are SpaceX satellites that comprise the Starlink mega-constellation. Ultimately, SpaceX hopes to have 42,000 satellites in orbit (Pultarova 2025). The commercial space age has arrived, bringing

with it both the possibilities and challenges of market-driven innovation and decision making.

## Benefits

As space launch capabilities improve and costs decrease, public and private actors are generating many economic, environmental, social and other benefits. While private companies have long played a role as contractors to support government initiatives, the new space age has created more direct and substantial opportunities for businesses to develop and deploy space technologies, create new markets and lines of business, and contribute to growth and employment. In 2022, the size of the space economy was an estimated \$447 billion<sup>4</sup> with more than 600 private space start-ups in operation. The space economy is expected to exceed \$1 trillion by 2030 with more than 1,000

3 See [https://space.skyrocket.de/doc\\_chr/la2023.htm](https://space.skyrocket.de/doc_chr/la2023.htm).

4 All dollar figures are in US dollars.

private companies offering space-based products and services (McKinsey & Company 2023).

In addition to direct economic benefits, private and public space innovators are generating benefits for communities, the environment and other economic sectors:

- Satellites and mega-communications constellations have improved access to internet and communications services in remote communities, developing countries and other locations facing barriers and disruptions to connectivity — at least among those who can afford receivers and service subscriptions. Better connectivity enables access to virtual health-care services, as well as taking on remote work opportunities, operating internet-enabled businesses, connecting with family and friends elsewhere, and furthering economic and social development more generally (Organisation for Economic Co-operation and Development [OECD] 2023).
- Infrastructure and climate change and environmental monitoring have benefitted enormously from space innovation. According to analysis by the OECD, space-based technologies “support more than half of the most frequently designated critical infrastructures and services” including transportation, energy, agriculture and law enforcement, while space-based observations “provide more than half of the essential climate variables that are used to monitor climate change” (ibid.).
- Benefits for the agricultural sector are especially impressive, with satellite technologies offering extensive information about crop, soil and water conditions, and GPS enabling precision farming and remote equipment operation — all of which may contribute to higher agricultural productivity and yields (New Space Economy 2023).
- Global positioning and navigation technologies have improved logistics in increasingly complex and fragmented global supply chains.<sup>5</sup> Tracking and rerouting deliveries facing weather-related, geopolitical or other disruptions are made much easier by technologies in LEO.

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5 See [www.unoosa.org/oosa/en/benefits-of-space/transportation.html](http://www.unoosa.org/oosa/en/benefits-of-space/transportation.html).

- Meanwhile, space innovation continues to support exploration and scientific discovery. Lower cost and more frequent launches have facilitated new initiatives and missions that improve our understanding of the universe and ourselves. The Planetary Society counts 65 major exploratory missions of our solar system currently under way or soon to launch — from the Artemis<sup>6</sup> program to land human beings on the Moon for the first time in more than 50 years to the Voyager<sup>7</sup> probes that have sent back stunning images of our solar system and are now exploring interstellar space.<sup>8</sup>

Combined with the social and economic benefits of spin-off technologies, these and other developments offer a strong case for supporting spacefaring. Indeed, while regulation and governance discourses often emphasize the negative dimensions, it is important to acknowledge that significant economic, social and environmental value is generated.

## Risks

Still, there are risks, some of which might outweigh the benefits that certain kinds of space activities generate. While national space agencies, private companies, scientists and international organizations are mapping, assessing and developing strategies to address some of the biggest risks, there remains substantial uncertainty about how spacefaring trajectories will play out, as well as insufficient coordination and cooperation to manage the risks that we already face (McClintock et al. 2021). And this was true long before the United States’ leadership role in space activities and governance has eroded under the Trump administration.

- Spacefaring poses environmental and economic risks from launch emissions, space debris and the potential to contaminate the ecosystems we visit (forward contamination) and Earth (backward contamination) following space missions (Hall 2024; Thomson 2024). With LEO becoming especially congested and near-collisions increasing in frequency, the likelihood of a catastrophic collision making LEO all but

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6 See [www.planetary.org/space-missions/artemis](http://www.planetary.org/space-missions/artemis).

7 See [www.planetary.org/space-missions/voyager](http://www.planetary.org/space-missions/voyager).

8 See [www.planetary.org/space-missions](http://www.planetary.org/space-missions).

unusable is within the bounds of possibility (Khatchadourian 2020).

- Military technologies and operations in space — such as intelligence, surveillance and reconnaissance satellites — both reflect and have the potential to exacerbate geopolitical tensions and conflict (Bingen and Williams 2024; Deudney 2020; West 2024; West and Miller 2023). Dual-use technologies that are ostensibly for peaceful purposes but in fact serve as or support military objectives are especially problematic, insofar as they can evade existing prohibitions on the weaponization of space (West and Miller 2023).
- As the number of and distances travelled by crewed missions increases — including those with well-trained astronauts and those with less well-prepared space tourists — risks to space travellers' health and well-being will become a greater concern (Krittanawong et al. 2023). While understanding of the effects of space travel and habitation on human health in LEO and for relatively short durations has improved, we know very little about the potential effects of longer missions and those in more hostile environments — such as dusty, windy Mars (Patel et al. 2020).
- Spacefaring also raises distribution questions and associated challenges. How space is used, for whose benefit, to whose detriment and with what opportunity costs are important and largely unanswered questions. If the distribution of space-related benefits and risks is intolerably unequal, it could undermine domestic and global support for spacefaring (Munro 2022). Why spend and cooperate on space rather than something with potentially more immediate economic or social value (Niiler 2019)? To be sure, distributive concerns are not new, as their inclusion in the OST reveals.<sup>9</sup> But how to define and operationalize a fair distribution remain open questions.
- Current spacefaring also poses risks to future space activities and innovation. This includes sequencing risks — where commercial activities such as mining, for example, could alter space environments before scientists have opportunities to study them properly (Haramia

2021); and first-mover disadvantages — where innovators who are currently placing moderately valuable objects in LEO prevent future innovators from using orbital space for higher value activities.

Again, governments, international organizations, private actors and others have developed treaties, policies, and technological and operational strategies to try to address some of the risks. While necessary and valuable, the achievements are too incremental and incomplete to secure space for the benefit of all humankind. Moreover, insufficient attention is being paid to how we can shape spacefaring futures in active, rather than reactive, ways. The technical capacity to mitigate and manage certain risks is often within reach, but the question of whether we should pursue activities that generate such risks in the first place is too often neglected.

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## What Is Responsible Innovation?

Responsible innovation offers a useful framework for guiding deliberation and decision making about scientific and technological activities (Stilgoe, Owen and Macnaghten 2013; von Schomberg 2015). From nuclear energy and biotechnology to automated vehicles and artificial intelligence, academics and practitioners have recognized that innovation can be directed away from negative and toward positive trajectories through social, political and economic mechanisms. Responsible innovation rejects the notion of “technological determinism” — that “technology, once invented, possesses an unstoppable momentum” (Jasanoff 2016, 14, 19). It emphasizes how technologies reflect human values and how we can “[take] care of the future through collective stewardship of science and innovation in the present” (Stilgoe, Owen and Macnaghten 2013, 1570; Zuboff 2019).

But how exactly does innovation stewardship work? How can an ideal of responsible innovation help move spacefaring along more positive, peaceful and inclusive trajectories? While the framework does not deliver ready-made answers, it offers five key criteria to guide deliberation

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<sup>9</sup> *Supra* note 2.

and decision making about more responsible innovation — including spacefaring:<sup>10</sup>

→ **Anticipation:** Responsible innovation asks us to think ahead. What benefits and risks might emerge if we direct innovation along one path rather than another? What plausible futures are enabled by different technology trajectories? Anticipation prompts us to imagine and assess future possibilities in order to select a favoured path and identify the resources, incentives and regulations that would help bring it about. In the case of spacefaring, anticipatory deliberation might reveal how a first-come, first-claimed approach to placing objects in LEO could block potentially more beneficial uses in the future.

There has not been a shortage of attempts to imagine possible space futures. Efforts by German, Russian and American rocket engineers throughout the twentieth century, for example, were motivated in no small part by reading Jules Verne's speculations about space travel in *From the Earth to the Moon* and *Around the Moon*, published in 1865 and 1869, respectively (Chaikin 1994; Harford 1997; Neufeld 2007). Speculative space futures are the horizons toward which both past and current spacefaring aim. The point of anticipation is to ask which of the possible futures can be realized and to rigorously consider their positive and negative implications.

→ **Reflexivity:** While anticipation helps us to identify possible futures and their implications, reflexivity prompts us to consider which possible futures *should* be realized. It asks us to step back and consider which innovation trajectories are consistent with core values or, in another vein, which trajectories would help us realize those values. Reflexivity is the most Arendtian criterion of responsible innovation. It entails “holding a mirror up to one’s own activities, commitments and assumptions; being aware of the limits of knowledge and being mindful that a particular framing of an issue may not be universally held” (Stilgoe, Owen and Macnaghten 2013, 1571). Reflexivity asks us to push against the myth of technological determinism and consider whether we *ought* to pursue certain activities or pursue them in different ways.

In his contribution to the Rogers Commission’s investigation into the causes of the 1986 Challenger disaster,<sup>11</sup> Richard Feynman pointed to National Aeronautics and Space Administration (NASA) managers’ failure to heed engineers’ warnings about the vulnerability of O-rings in cold weather as a key factor. That failure, in turn, was a consequence of prioritizing speed, efficiency and strict adherence to launch schedules over risk management, which, Feynman speculated, were part of “an attempt to assure the government of NASA perfection and success in order to ensure the supply of funds” (Feynman 1986). NASA managers made poor choices because they did not reflect on and revise the values driving their decision making. In his “minority report,” which ironically was nearly excluded from the commission’s submission because it was considered embarrassing to NASA, Feynman concluded that “for a successful technology, reality must take precedence over public relations, for nature cannot be fooled” (ibid.).

→ **Inclusion:** Anticipation and reflection can be enhanced by including more voices. Too often, decisions about science and technology trajectories are made by scientists, innovators, financiers and regulators, with minimal input from people who are affected by and who should have a say in what shared futures look like. When it excludes or marginalizes public contributions, deliberation reinforces technocratic biases, narrow interests and power imbalances. Responsible innovation calls for inclusive deliberation to enhance the legitimacy of decisions and the quantity and quality of information that shapes them (Fischer 2009; Fung and Wright 2003; Jasanoff 2016; Stilgoe, Owen and Macnaghten 2013).

Surveys of American public attitudes have revealed muted levels of support for space activities since the 1960s, and even lower support among women and Black Americans (Launius 2003; Madrigal 2012; Whitman Cobb 2023). A recent survey on attitudes to commercial space activities found that just 25 percent of respondents agreed or strongly agreed that human spaceflight should be done by private companies, versus 32 percent who disagreed or strongly disagreed (Whitman

10 Four criteria are adapted from Stilgoe, Owen and Macnaghten (2013) while a fifth — distributive fairness — is added to fill what we perceive to be a gap in existing responsible innovation frameworks.

11 See [www.history.com/this-day-in-history/January-28/challenger-explodes](http://www.history.com/this-day-in-history/January-28/challenger-explodes).

Cobb 2023, 170–1). Forty-three percent of respondents were “neutral.” Low public support sits uncomfortably beside the proliferation of commercial space activities, often supported by public resources. If spacefaring is to achieve long-term legitimacy, decision makers will need to engage the public more directly.

→ **Responsiveness:** Responsible innovation must be responsive in two senses. First, deliberation is responsive when it adjusts to changing circumstances and agents. As Jack Stilgoe, Richard Owen and Phil Macnaghten (2013, 1572) note, responsiveness is the “capacity to change shape or direction in response to stakeholder and public values and changing circumstances.” The alternative is allowing trajectories and their consequences to unfold “through drift and inadvertence” — an approach that some participants regarded as a source of moral failure in the Manhattan Project to build the atomic bomb (Munro 2018).

In a second sense, responsiveness requires empowering participants to shape decisions and activities rather than simply consulting them for public relations reasons. In that case, responsiveness aims to address one of the deficiencies of contemporary public consultation processes that canvas a wide range of perspectives but do so with little intention of having those perspectives affect decisions (Fung and Wright 2003).

In early 2024, the privately owned Peregrine spacecraft launched with hopes of landing on the Moon carrying, among other things, the remains of 95 people and one dog (Bartels 2024). While the spacecraft had difficulties after liftoff and never reached the Moon (Amos 2024), members of the Navajo Nation were upset that it launched at all, arguing that dispersing human remains desecrates the Moon and that they had not been consulted. While there is room for disagreement about whether human remains belong on the Moon, Peregrine launched without engaging the Navajo or other Indigenous groups despite a NASA spokesperson promising 20 years earlier that they would be consulted on such activities in the future (Bartels 2024). Spacefaring will face a substantial legitimacy gap if decision making is not informed by and responsive to public engagement. A key challenge here will be institutionalizing responsiveness — that is,

identifying who or what must be responsive to whom, exactly. These issues are taken up later in this paper.

→ **Distributive fairness:** Innovation has uneven distributive consequences. While some people and communities participate in and benefit from innovation, opportunities and benefits are out of reach for others. Moreover, harms associated with new technologies often fall disproportionately on already marginalized communities. As Stilgoe (2020, 29) notes, “innovation is double-edged. The justification is often that the benefits outweigh the risks, but the issue is that the people benefitting are not normally the ones bearing the burdens of innovation.” Studies of “inclusive” and “distribution-sensitive” innovation make the case that a more equitable distribution of opportunities, benefits and harm contributes to better and more legitimate innovation (Munro 2020; Munro and Zachariah 2021; Paunov 2017; Zehavi and Breznitz 2017).

Space innovation advocates have been slippery on the issue of fair distribution, maintaining that exploration and innovation benefit everyone while struggling to provide evidence for the claim. They point to “spinoff” technologies that may (or may not) improve economic and social well-being; they highlight advances in science, our understanding of the universe and our place in it; and they emphasize the ways spacefaring inspires new generations of scientists and innovators. These are all great benefits, but they are not widely shared — a point that many poor and Black Americans have long emphasized (Madrigal 2011; Maher 2017; Niiler 2019). Moreover, less-developed countries have watched as a handful of more developed countries and private companies claim prime locations in space and threaten sustainability despite international treaties maintaining that space activities should be “carried out for the benefit and in the interests of all countries.”<sup>12</sup>

## Challenges for Responsible Innovation

A framework for responsible space innovation faces two main criticisms — neither of which is fatal to the approach but they do require attention.

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<sup>12</sup> *Supra* note 2.

One line of criticism holds that responsible innovation frameworks might impair innovation. The concern echoes a long-standing and pervasive view that regulation is a barrier to innovation. To be sure, regulation is a barrier in some cases — and arguably should be when certain innovations and technologies pose substantial risk. But regulation and, by association, a framework for responsible innovation, also serves as a precondition for successful innovation. Innovators often appreciate the clarity that emerges from regulation about what will and will not be permitted because it helps them invest with greater certainty and offers a level playing field with other innovators (Bednar 2022; Stilgoe 2020).

Responsible innovation properly applied does not seek to block innovation; it aims to *enable* the kinds of innovation that genuinely benefit people, communities and other stakeholders. While that means innovation might be slowed temporarily to allow time for robust deliberation, once shared aims and preferred trajectories are identified, innovators are able to pursue their activities with more certainty and legitimacy than they would in the absence of deliberation.

A second concern is that responsible innovation is idealistic and impractical. Responsible innovation asks goal-oriented, powerful actors to step back from their activities, temporarily relinquish power and engage in reflection with others about whether current trajectories are morally worthwhile. Moreover, responsible innovation makes this request in the context of a hyper-competitive global environment where many of those with power would rather push their own agendas through than cooperate with others. Combine this with the fact that reasonable stakeholders will disagree about core values and purposes, as well as what weight should be given to shared but different values (such as exploration, economic growth and environmental protection), and the prospects for agreement about how to use space responsibly appear limited.

The criticism has force. International cooperation is a perpetual challenge. But the criticism may be stated too strongly and with little recognition that cooperation does in fact occur. From the OST to Russian-American cooperation on the International Space Station and emerging transparency about and coordination on managing objects in LEO, spacefaring states have demonstrated a capacity to agree on principles and cooperate

on shared interests. Responsible innovation does not deny that cooperation is difficult, but it rejects the idea that it is impossible. The key is to find spaces where different stakeholders can come together to articulate their aims, listen to the concerns of the others — including marginalized states and peoples — and work toward acceptable principles for coordination.

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## Realizing Responsible Space Innovation

Despite glimmers of possibility and occasional breakthroughs, spacefaring has neither aligned with nor been shaped by the principles of responsible innovation in any substantive way. While recent initiatives and developments suggest the underlying principles of responsible innovation may be gaining traction, this tends to be implicit and partial at best. Examining three current issues and initiatives — activities in LEO, space-based mining and the Artemis mission — provides a better understanding of what responsible innovation can offer in shaping space futures.

### Space Innovation in LEO

The new space age has largely focused on the use of LEO to generate benefits for people and communities on Earth. Deployment of satellites for communications, observation and navigation purposes have fundamentally changed how many social and economic activities are conducted. Earth-based transportation, communication and manufacturing infrastructures — as well as current and future space missions — depend on a space-based infrastructure of satellites and mega-constellations. At the same time, this space-based infrastructure is fragile, imposes environmental costs, complicates observation and study of the night sky, and poses challenges to new missions in LEO and beyond.

Space activities in LEO exhibit some features of a responsible innovation approach but would benefit from much more. In some ways, space innovators working in LEO engage in *anticipation* and *responsiveness*. Space actors are aware of collision risks and their potentially catastrophic consequences and have taken steps to address

them, including new rules on de-orbiting satellites (Federal Communications Commission 2022); new technologies to assist with space junk retrieval (Khatchadourian 2020); and ongoing cooperation through the United Nations' Inter-Agency Space Debris Coordination Committee to share information about space debris and collision mitigation options. Key actors have imagined future scenarios and are taking steps to avoid those deemed intolerable.

At the same time, the monitoring and mitigation efforts are widely regarded as insufficient to meet the collision risks posed by the accelerating pace of object deployment in LEO and already existing debris (Byers and Boley 2023), as well as the environmental risks of hundreds of launches every year and the diffusion of potentially harmful particles in Earth's upper atmosphere from object burn-up on re-entry (Hall 2024). Additionally, current efforts do little to anticipate and respond to the damage being done by the expansion of LEO activity to access to space for developing countries and future innovators. Anticipatory thinking about how to use LEO has focused narrowly on technical issues of coordination and collision avoidance, and barely at all on deeper questions about what we should and should not be doing, who benefits, who is excluded and what different trajectories we might consider.

In short, the state of deliberation about LEO fails to meet the responsible innovation criteria of reflexivity, inclusion, responsiveness and distributive fairness. That matters not only for normative reasons, but for practical reasons as well. By allowing current trajectories to unfold without "thinking what we are doing," we run the risk of sabotaging future space opportunities and benefits, and the well-being of life on Earth more generally.

## Space Resources

Interest in mining or otherwise extracting resources such as water from planets, moons and asteroids has increased in recent years, largely for two reasons. First, extracting resources from off-Earth locations could facilitate easier and lower-cost exploration of space. If water and other resources can be gathered from the Moon and other lower-gravity locations, for example, long-range space missions would be able to launch from Earth without carrying the weight of additional fuel. Spacecraft would be able to make pit stops on the Moon or elsewhere to pick up fuel and supplies. The second motivation is economic.

Some people and organizations believe that space mining can generate billions in revenue. Mining resources from the 10 most cost-effective near-Earth asteroids, according to one estimate, could generate \$1.5 trillion in profits (Yarlagadda 2022).

With these rationales in mind, firms and countries are competing to establish resource claims. For example, the US Commercial Space Launch Competitiveness Act (2015) attempts to establish US citizens' entitlement to "possess, own, transport, use, and sell [an] asteroid resource or space resource obtained in accordance with applicable law, including the international obligations of the United States."<sup>13</sup> The US position has been criticized by China, Russia and others for potentially violating the OST's provision that "outer space, including the moon and other celestial bodies, is not subject to national appropriation" and the Moon Agreement's prohibition on ownership of parts of the Moon (Munro 2022). At the same time, China has its own Moon mining ambitions and recently brought samples from the Moon back to Earth — just the third state to do so (Byers and Boley 2023, 131). The space resource race is under way.

It may be that use and even ownership of space resources can be justified within international law (Byers and Boley 2023), and there may be good reasons for doing so. A responsible innovation approach, however, would ask not merely whether resource extraction is permissible, but whether it is reasonable, or reasonable with certain aims and conditions. So far, deliberation about space resources has not relied on responsible innovation criteria. While key actors have *anticipated* a narrow suite of possible futures for space resources and are rushing to realize their preferred futures, decision making has not been measurably influenced by processes of *reflexivity, inclusion, responsiveness* or *distributive fairness*.

The OST and Moon Agreement articulate inclusive and equitable visions — aspiring to have space and its resources benefit all humankind, and even calling for "special consideration" to the needs and interests of "developing countries."<sup>14</sup> Moreover, the agreements prioritize exploration over commercial

13 U.S. Commercial Space Launch Competitiveness Act, Pub L No 114-90, 129 Stat 704 (2015), online: <[www.congress.gov/bill/114th-congress/house-bill/2262/text](http://www.congress.gov/bill/114th-congress/house-bill/2262/text)>.

14 Agreement Governing the Activities of States on the Moon and Other Celestial Bodies, 5 December 1979, Res 34/68, 1363 UNTS 3 (entered into force 11 July 1984), online: <<https://treaties.unoda.org/t/moon>>.

purposes. In that case, international law and deliberation embody key elements of a responsible innovation approach to space resources. There are also international non-governmental organizations (NGOs) thinking about space mining and resource extraction in more reflective ways, with a concern for sustainability especially prominent (Osburg and Lee 2022). These include the Hague International Space Resources Governance Working Group,<sup>15</sup> the Secure World Foundation<sup>16</sup> and the United Nations Office for Outer Space Activities' Working Group on Legal Aspects of Space Resource Activities.<sup>17</sup>

The behaviour of states, however, is something else. Space resource plans and activities are being pursued largely unilaterally, with efforts to secure prized locations taking priority over careful reflection about what we should and should not do in space — as well as how extractive and competitive activities in space affect life on Earth. Do we want a future in which objects and locations in outer space are effectively owned and used for commercial purposes? Do the benefits of resource extraction that supports exploration outweigh environmental and political risks? How should the opportunities and benefits of accessing space resources be distributed? These and other questions are being asked but not in the right places and not with powerful decision makers sincerely committed to reshaping their activities in response to deliberative outcomes.

## The Artemis Missions

If responsible innovation has been largely absent from deliberation about the use of LEO and space resources, its principles have appeared in discussions about the Artemis program<sup>18</sup> — the effort to land humans on the Moon as part of a longer-term effort to reach Mars. The high-level aims of the Artemis program are “scientific discovery, economic benefits, and inspiration for a new generation of explorers.”<sup>19</sup> More concretely, NASA and its international and commercial partners hope to develop technologies and leverage resources, both on Earth and off, to solve challenges and

chart a course for a Mars mission. While many decisions about purposes and planning for the Artemis missions have already been completed, the program has embraced opportunities for broader and more inclusive thinking about the aims and direction of spacefaring and made efforts to ensure that deliberation is more inclusive.

### Artemis Accords: Reflection and (Partial) Inclusion

Notably, the program has seen substantial negotiation and signing of bilateral agreements with 56 countries (as of July 2025) to foster participation and cooperation in space.<sup>20</sup> According to NASA, the Artemis Accords are rooted in the principles of the OST and “reinforce the commitment by the United States and signatory nations to the Registration Convention, the Rescue and Return Agreement, as well as best practices and norms of responsible behavior” including using space for peaceful purposes, transparency, interoperability, data sharing, preserving outer space heritage, and managing orbital debris, among others.<sup>21</sup>

Both the process and content of the accords align to some extent with responsible innovation principles of reflexivity (about purposes) and inclusion (of some countries) — though there is skepticism about whether the accords are consistent with the OST and concern that they have been “created outside multilateral fora — such as the United Nations Committee on the Peaceful Uses of Outer Space (COPUOS) — where international space law has historically been made” (Chasmar 2024). And it remains to be seen whether other responsible innovation principles — such as anticipation, responsiveness and distributive fairness — will play a role.

### Artemis, Ethics and Society: Anticipation, Reflection and (Partial) Inclusion

At the same time, NASA's Office of Technology, Policy, and Strategy (OTPS) convened an Artemis, Ethics and Society (AES) workshop to identify and discuss some of the larger social and ethical questions and implications of the program. A report following the workshop noted that “NASA

15 See [www.universiteitleiden.nl/en/law/institute-of-public-law/institute-of-air-space-law/the-hague-space-resources-governance-working-group](http://www.universiteitleiden.nl/en/law/institute-of-public-law/institute-of-air-space-law/the-hague-space-resources-governance-working-group).

16 See [www.swfound.org/](http://www.swfound.org/).

17 See [www.unoosa.org/oosa/en/ourwork/copuos/lsc/space-resources/index.html](http://www.unoosa.org/oosa/en/ourwork/copuos/lsc/space-resources/index.html).

18 See [www.nasa.gov/humans-in-space/artemis/](http://www.nasa.gov/humans-in-space/artemis/).

19 Ibid.

20 See *Artemis Accords*, 13 October 2020 (not yet entered into force), online: <[www.nasa.gov/wp-content/uploads/2022/11/Artemis-Accords-signed-13Oct2020.pdf](http://www.nasa.gov/wp-content/uploads/2022/11/Artemis-Accords-signed-13Oct2020.pdf)>.

21 Ibid.

has not...systematically addressed the societal and ethical implications of human exploration” (Pirtle, McBrayer and Beauchemin 2023). To help repair that deficit, the OTPS brought together 55 experts from various academic disciplines and NGOs, as well as NASA technical staff and management, to address two key questions: How should NASA consider the ethical, legal and societal implications of the Artemis and Moon-to-Mars efforts? And what are the key ethical and societal implications that require consideration? “Including ethical and social considerations in Artemis planning,” the report’s authors asserted, “will improve the likelihood that the future we create is one where humanity collectively wants to live” (ibid.).

While the AES initiative’s impact on NASA’s broader activities is unclear, it does reflect three features of responsible innovation. By prompting participants to look ahead at possible implications of missions, the workshop supported future-oriented *anticipatory* thinking. Moreover, by encouraging participants to discuss the social and ethical implications — and not merely technical considerations — of the missions, the AES provided a forum for *reflexivity*. This was helped in part by the questions posed by organizers, but also by efforts to achieve some measure of *inclusion* — that is, philosophers, sociologists, historians and other academic experts in discussion with NASA technical staff and management. While greater public participation would have been beneficial, the AES workshop was nevertheless a promising effort to consider space innovation through a responsible innovation lens (Munro 2023).

That said, the AES initiative falls short on responsible innovation criteria of *responsiveness* and *distribution*. Although NASA has used the initiative in part as a springboard to develop and have its officials talk about a new strategy for sustainability in space (Doyle 2024), it is not clear that NASA or the OTPS have concrete plans to reshape other activities in light of the conclusions of the workshop, nor any plans to extend the initiative itself by convening more discussion. Indeed, in the current political climate, pessimism is the best bet. Moreover, while participants in the workshop raised questions and concerns about the distribution of opportunities, benefits and risks from the Artemis program and spacefaring generally, issues of distributive fairness do not seem to have achieved traction following the release of the workshop report.

While the Artemis Accords have questionable motives and potential conflicts with existing international agreements, and the AES workshop was limited in scale and impact, both offer positive signals about the desirability and possibility of incorporating the principles of responsible innovation into deliberation about space innovation. A more robust responsible innovation approach to the Artemis program would entail explicit engagement with all five criteria, allocation of resources to ensure conversations such as those initiated by the AES become regular rather than ad hoc events, and making better use of existing international fora, such as COPUOS, to convene discussion and reach agreements.

### The Persistence of Competition: China and Russia’s International Lunar Research Station

The Artemis Accords and associated ethics activities offer some hope that a responsible innovation approach to spacefaring is possible, if not yet sufficiently operationalized. But that optimism should be diminished by the fact that two of the other major spacefaring nations — China and Russia — and some of their allies, are moving independently on their lunar ambitions.

China and Russia are racing to establish their International Lunar Research Station (ILRS) on the Moon and thereby stake a use claim before the Artemis partners can execute their own plans (Nesvold 2025). The partners have worked with agencies of the United Nations, experts from France, Germany, Switzerland and other countries, and other national governments to discuss and develop their plans, which suggests awareness of the need to garner some international legitimacy. Moreover, the ILRS partners have articulated principles of cooperation — including peaceful exploitation, joint discussion, sharing of scientific outcomes and the formation of cooperative outcomes — which suggests an openness (whether sincere or strategic) to responsible spacefaring (China National Space Administration 2023).

The upshot, however, is that there are now two blocs — the ILRS partners and Artemis partners — with competitive lunar ambitions. That distinct plans exist at all demonstrates a major gap in the collaborative intentions of both the ILRS and Artemis partners. More importantly, that the two groups are effectively racing to the Moon to establish “keep-out” zones (Nesvold 2025) — rather than working together

to develop and abide by shared standards — suggests that competitive geopolitics continues to outweigh responsible innovation as the norm in spacefaring. While the OST and its normative framework are still in force, the behaviour of spacefaring nations is straining its principles.

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## Hopeless Thinking?

Apollo 11 landed the first men on the Moon in 1969 — just 12 years after Sputnik orbited the Earth and accelerated exploration and competition in space. According to popular history, the first space race reflected the tense Cold War politics of the time. Shocked that the Soviets had the capacity to send a satellite around the Earth, and thus potential to hit America with a long-range missile, the United States pursued its space program with the resources and zeal of a country that believed itself to be at great risk. The Americans were right to worry. While Soviet rocket engineers and cosmonauts were genuinely interested in exploration, Soviet leadership viewed their space program as a way to develop and demonstrate intercontinental missile capacity and boast about the virtues of socialism (Siddiqi 1998). By 1964, the Soviets saw that competing with the United States would require Moon ambitions of their own.

At the same time that geopolitical and military considerations were driving the space programs of both great powers, a companion narrative about science, exploration and peaceful uses of outer space was gaining traction. In the early years of the race, many Americans' visions of space reflected late 1950s, Jules Verne-inspired episodes of *Disneyland* — “Man in Space” and “Mars and Beyond” — that featured NASA rocket engineer Wernher von Braun explaining the wonders and possibilities of space travel (albeit without revealing his Nazi past). By 1967, aspirational ideals of peaceful uses of space for the benefit of all humankind were enshrined in the OST. Positive spacefaring futures were being imagined and developed alongside Cold War space race tensions.

In a 1936 essay, long before the first space race, the novelist F. Scott Fitzgerald wrote that “the test of a first-rate intelligence is the ability to hold two opposed ideas in the mind at the same time, and still retain the ability to function” (Fitzgerald

1936). Spacefaring from 1957 to at least the 1980s required observers to rise to Fitzgerald's test: At the same time that space activities were being driven by Cold War politics, there were also examples of humanity's ability to use science and technology to explore and use outer space for peaceful purposes.

The two space narratives crossed paths in a stunning way in July 1975 when an Apollo spacecraft launched with three American astronauts on board and docked two days later with a Soyuz spacecraft that had two Soviet cosmonauts on board. The result of years of behind-the-scenes planning and negotiation, and ostensibly a test of rendezvous and docking capabilities to support future potential rescue missions, the Apollo-Soyuz Test Project was the first international space mission (Uri 2022). After nearly two decades of intense competition and still in the midst of the Cold War, the United States and Soviet Union demonstrated that cooperation in space was possible.

Hannah Arendt, who in the 1950s called on a newly spacefaring humanity to “think what we are doing,” died in 1975 — the same year as the Apollo-Soyuz Test Project. She had witnessed and worried about Sputnik, the Apollo missions and the persistent contradictions and moral risks of spacefaring. And yet, in the year Arendt died the world was offered an inspiring example of cooperative and peaceful action in space. A responsible innovation approach to spacefaring and governance may seem naïve — and arguably more so now than at any point in the space age — but history reveals that aspirational frameworks can lead to tangible results. As Fitzgerald (1936) wrote, “one should...be able to see that things are hopeless and yet be determined to make them otherwise.”

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